EXPLORING DEEPER RESERVOIR POTENTIAL IN EAST BALINGIAN BASIN, OFFSHORE SARAWAK

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ABSTRACT

East Balingian province is part of the bigger Balingian basin of offshore Sarawak. It is a proven petroleum system, with more than 10 oil and gas fields producing in present day. With more wells drilled, more hard data from the fields are made available from core and cutting samples. These are the main tools in understanding the reservoir better, especially its facies type and what is controlling the reservoir quality in terms of porosity and permeability. This understanding of facies is then crucial to determine the prospectivity of the unexplored deeper structures within the East Balingian basin. There are 23 wells data used in this study that includes petrography, XRD, geochemical, DST, well logs, pressure and temperature data. However, only two wells were drilled deeper than 2500 meter subsea. From porosity plot with depth, it was observed in general that porosity decreases with depth, at which the critical porosity floor is at 2200 meter subsea (porosity mostly lesser than 10%). The study found that the reservoir quality was mainly controlled by mechanical compaction, overpressure, temperature, chemical diagenesis that formed diagenetic minerals surrounding grains surfaces and in the pore throat, facies grain sizes and clay content of the reservoir rock. It was observed that reservoir quality for depth deeper than the 2200 meter subsea can be preserved by having overpressure, bigger grain sizes and lower clay content (volume of shale value less than 15%). This makes deeper reservoir prospectivity potential possible in the East Balingian basin, which currently still remains underexplored. This ability to predict reservoir quality may also assist reservoir engineers to predict reservoir flow rate, recovery factors and production profile beforehand, which are needed to deduct whether the fields are economic to drill or not. This will then lead to an increase of hydrocarbon reserve in Malaysia and contribute to the economy of the country.

ABSTRAK

Wilayah Balingian Timur ialah sebahagian daripada lembangan Balingian yang terletak di perairan Sarawak. Kawasan ini sudah terbukti mempunyai simpanan minyak dan gas, dengan lebih daripada 10 buah medan menghasilkan minyak dan gas pada masa kini. Dengan meningkatnya bilangan telaga minyak yang digerudi, lebih banyak maklumat tentang batuan reservoir berjaya diperoleh menerusi sampel teras dan keratan. Semua sampel itu menjadi keperluan utama bagi memahami geologi batuan reservoir dengan lebih baik, terutama untuk mengetahui jenis fasies yang terdapat di kawasan itu termasuk faktor yang mengawal kualiti batuan dari segi keliangan dan kebolehtelapan. Pemahaman tentang fasies adalah penting bagi mengenal pasti prospek kawasan yang kurang atau belum diterokai terutama pada kedalaman yang lebih dalam. Data daripada 23 buah telaga minyak dan gas, yang mencakupi data petrografi, geokimia, informasi log, ujian batang gerudi, tekanan, dan suhu telah digunakan dalam kajian ini. Namun hanya dua daripada telaga itu yang mempunyai kedalaman yang melebihi 2500 meter di bawah paras laut. Hubungan peratus keliangan dan kedalaman menunjukkan bahawa keliangan batuan semakin berkurang apabila kedalaman telaga meningkat. Kedalaman 2200 meter di bawah paras laut ditandai lantai kritikal bagi keliangan di kawasan terbabit. Hasil analisis menunjukkan bahawa kualiti batuan reservoir di Balingian Timur dikawal oleh pemadatan mekanikal, tekanan lebihan, suhu yang tinggi, proses kimia yang menghasilkan mineral diagenesis, saiz butiran dan kandungan lempung di dalam batuan. Kualiti batuan boleh dikekalkan pada kedalaman yang melebihi 2200 meter di bawah paras laut dengan wujudnya tekanan lebihan yang mampu mengurangkan kesan pemadatan mekanikal, saiz butiran di dalam batuan yang lebih besar dan kandungan lempung yang kurang daripada 15%. Hasil kajian berjaya mengetengahkan potensi batuan reservoir minyak dan gas pada kedalaman yang lebih dalam di Balingian Timur, yang masih kurang diterokai sehingga kini. Kemampuan untuk meramal kualiti batuan reservoir juga penting bagi membantu para jurutera dalam meramal kadar aliran cecair di dalam batuan dan faktor pemulihan maksimum. Kajian ini juga boleh meningkatkan rizab petroleum negara yang mampu menyumbang secara positif kepada ekonomi.

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CHAPTER 1

INTRODUCTION

1.1 Background

Petroleum industry is one of the main economic contributors to Malaysia. The country has been producing oil and gas from petroleum basins which scattered over the peninsular Malaysia, Sarawak and Sabah. The industry contributes incomes to Malaysia and has created numerous job opportunities for the people.

Figure 1.1 shows the distribution of hydrocarbons producing basins in Malaysia which have been explorationists attractions from countries around the world. The first discovery was made in onshore Sarawak, in which the first well was drilled on 10 August 1910 in Miri, well-known as the *Grand Old Lady* (Shell, 1978). Sixty years later, the first offshore well was drilled off the Baram point and marked the starting journey of offshore exploration in Malaysia. Since then numerous wells have been drilled in offshore Sarawak, testing multiple plays, from shallow water clastics, to carbonates pinnacles.

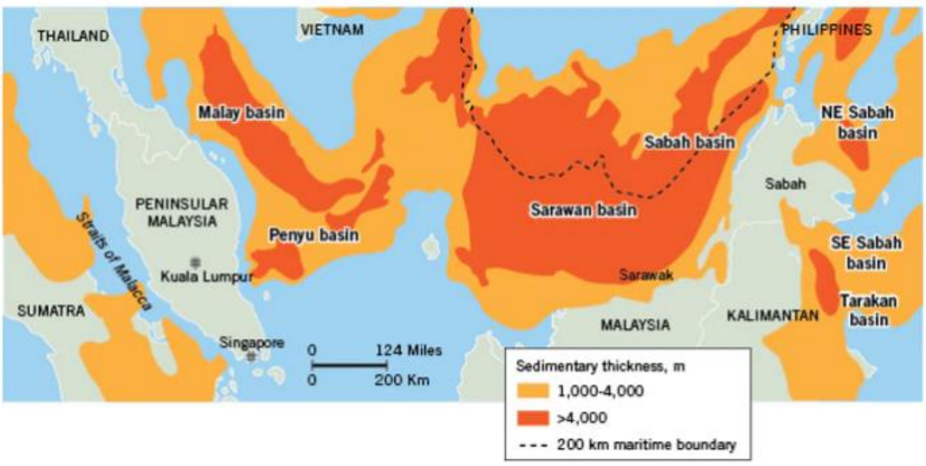

Figure 1.1 Distributions of petroleum basins in Malaysia (PETRONAS,1999)

These discoveries are mainly driven by success stories through exploration. Exploration is the stage at which wildcat wells are drilled to find commercial amount of oil and gas in a field. Only then the field will be appraised, developed and goes on production. It is therefore crucial to make good technical decisions in the exploration stage to reduce the risk of drilling dry wells. Explorationists should be able to identify all the key elements of an oil and gas structures which include the trap, seal, reservoir presence and quality, migration pathways and source rocks.

1.2 Problem Statement

Figure 1.2 shows the location of Balingian basin in offshore Sarawak where major hydrocarbon fields of Sarawak are located. An example is the Temana field which has been producing for 40 years (still producing in present day) from the clastic reservoirs of Late Oligocene to Early Miocene age. Being a major hydrocarbon producer, source rocks maturity and migration pathways are not a concern in this basin. Traps can be well identified through seismic, and seals are mostly provided by good extensive shale. However, reservoir quality can be unpredictable. Reservoir remains as one of the key risks in exploration drilling due to the lack of ability to predict reservoir quality beforehand. Figure 1.3 shows the main reservoir target interval in Balingian basin, highlighted in red box. The prospective interval consists of stacked lower to upper coastal plain reservoirs. As reference, this study will be using the cycles nomenclature for reservoir naming (Cycles I, II and III).

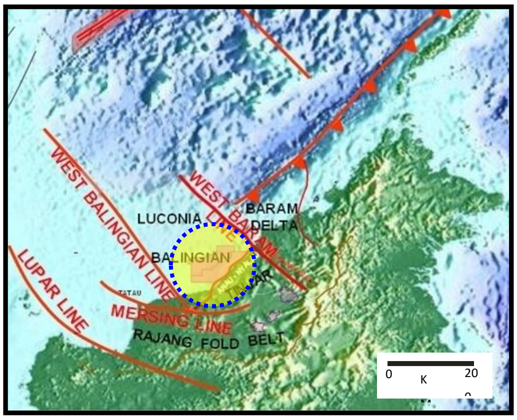

Figure 1.2 Location of Balingian basin in offshore Sarawak (Noorhashima, 2018)

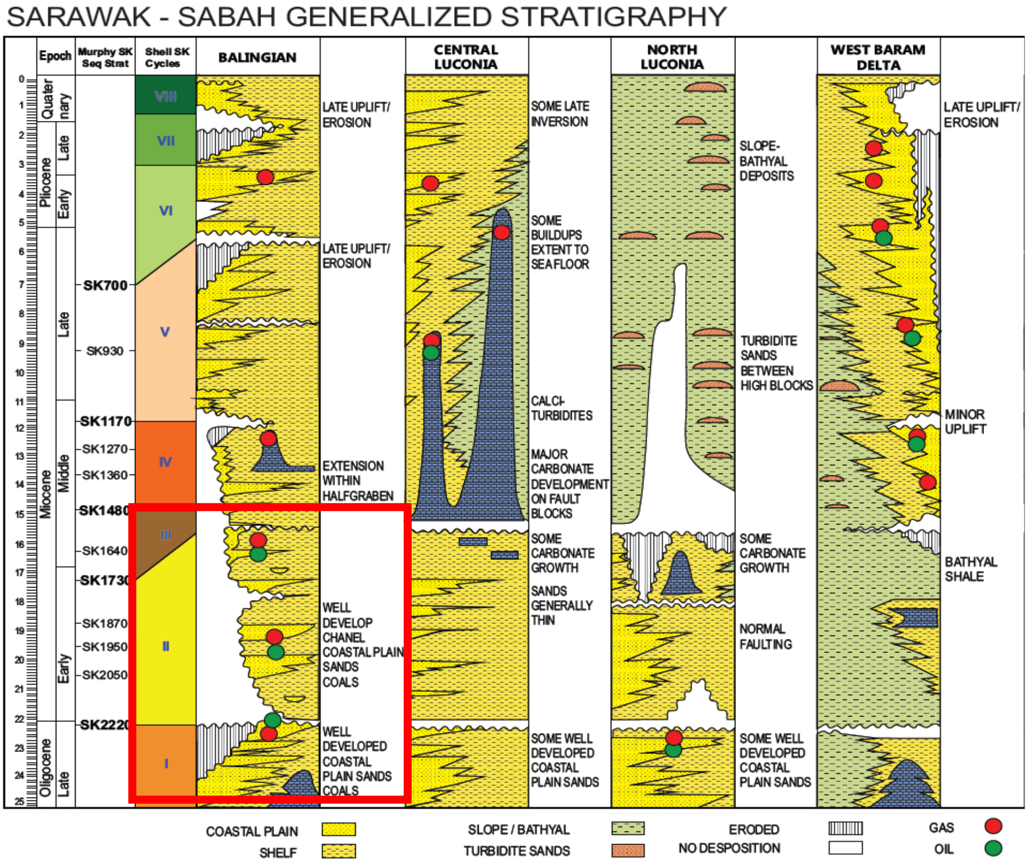

Figure 1.3 Main reservoir target interval in Balingian basin (red box) (Teguh, 2009)

Figure 1.4 shows a plot of porosity versus depth for reservoirs in five wells in Balingian basin (Noorhashima and Teguh, 2018). The well correlation of the five wells shows the changes of depositional environment from West to East (as shown in the map). The coal stringers found in well H-4RD and I-2 indicate coastal plain environment, which then changes into a transition towards shallow marine environment going to East towards J-1 well shown by the occurrence of limestone stringers. Further east, the depositional environment changes into shallow marine environment, shown by the presence of carbonate pinnacles found in K-1 and L-1 wells. The reservoir targets are divided into two intervals, the shallow target which is of Cycle III and younger, and the deeper target which is of Cycle II and older.

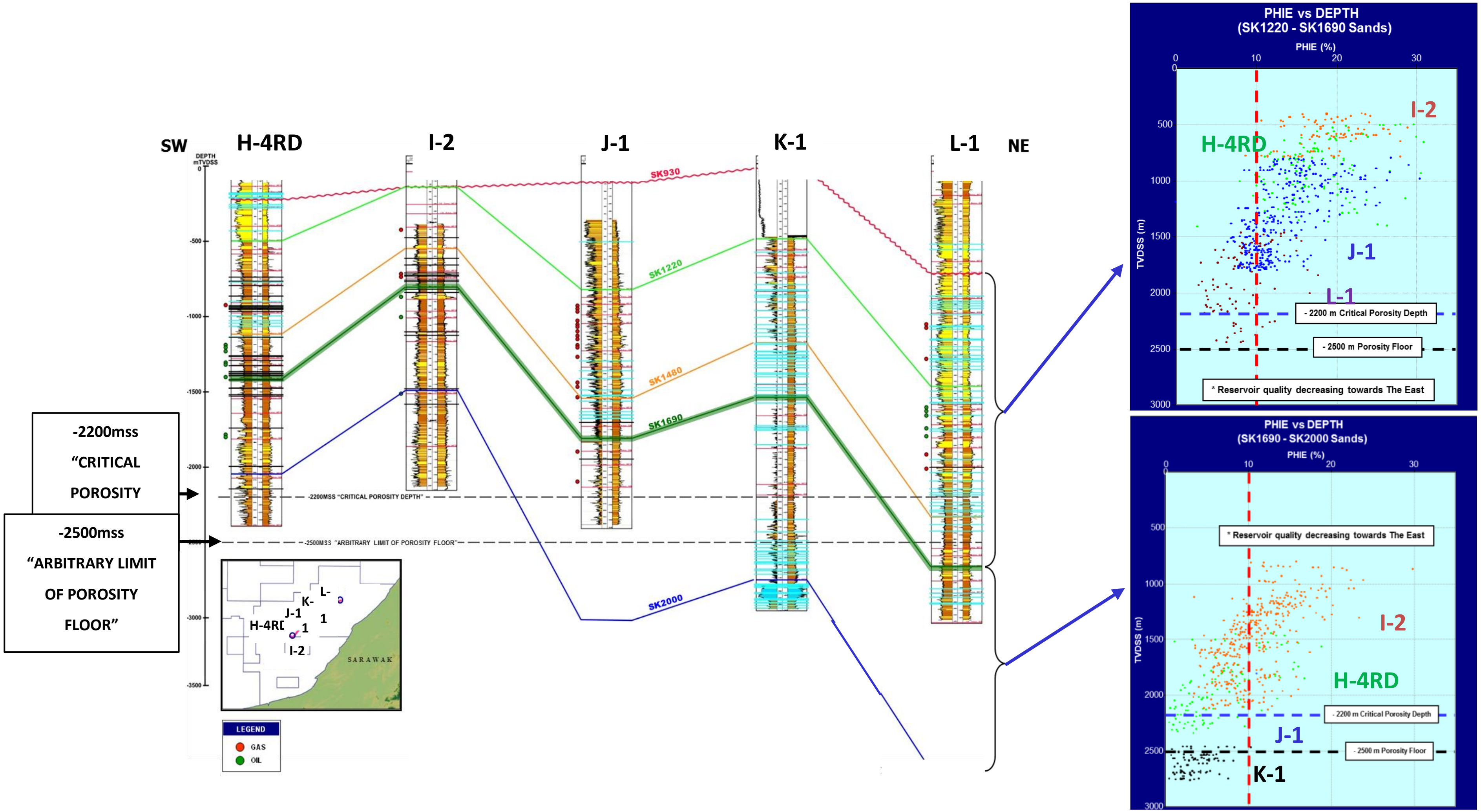

Figure 1.4 Porosity plot versus depth (Teguh, 2009)

The porosity plot shows that for both reservoir targets, porosity deteriorates with depth. Twenty two hundred meter subsea (is then written as mss) is set as the critical porosity floor where porosity falls below 10% and 2500 mss as the arbitrary limit of porosity floor. For both shallow and deeper targets, reservoirs porosities are good within the I-2 well where the reservoirs are uplifted to shallower depth, as compared to other wells. This agrees with the theory of compaction effect as rocks got buried deeper (Earle, 1984). In addition to that, the reservoirs in I-2 wells are also of a coastal plain environment, shown by the numerous coal stringers, where rock facies are expected to be of better quality, with bigger grain size and good sorting (Ann *et al*., 2015*)* compared to other wells drilled in reservoir of different environments, where rock facies are of smaller grain size and poorer sorting.

This deterioration in reservoir quality has limited exploration of reservoirs below 2000 mss in the East Balingian basin. Little was known to this deeper reservoir potential and therefore are in need to be explored. Therefore, it is important to pinpoint the controlling factor of the reservoir quality in this area so that explorationists are able to predict reservoir quality better. Was its burial depth or the facies type related to depositional environment? Understanding the effect of facies can also help to minimise reservoir risk factor in assessing prospects and therefore opening up more new plays to drill in the future. With the increasing number of wells drilled in the area, more hard data are made available (eg. cuttings, cores, logs, etc.) and can be studied to understand this better.

1.3 Hypotheses

The hypotheses of the research are:

(1) Reservoir quality may be related to facies in terms of:

- Compaction (burial diagenesis); reduce poro-perm
- Chemical diagenesis; presence of diagenetic minerals such as overgrowth quartz, clay, siderite, ferroan dolomite. May either reduce poro-perm or enhance it by dissolution
- Reservoir grain size and sorting

- Reservoir cleanness: Lower volume of shale (Vsh) value will give better poro-perm
- Structural history: has it been buried deeper before?

(2) Reservoir quality may be preserved, even in deeper depth, depending on its facies type and therefore should be tested and explored more.

1.4 Research Objectives

The objectives of the research are:

(1) To establish the relationship between facies type and reservoir quality in Balingian basin, offshore Sarawak

(2) To upgrade deeper reservoirs potential prospectivity in Balingian basin.

1.5 Research Scope

Numerous wells have been drilled over the years, making more available hard data acquired from the wells. Therefore, the research scope includes:

(1) Collecting all available data; logs, core samples analysis, pressure plots, etc.

(2) Collecting all available lab reports; petrography analysis, XRD and geochemical analysis, isotope analysis, etc.

(3) Analysing all data: Comparing the rock data between fields and identify trends and anomalies, and analyse the results.

(4) Establish relationship between facies and reservoir quality.

(5) From the relationship, and data available from deeper reservoir, analyse how good reservoir quality can be preserve at deeper depth and upgrade the prospectivity.

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